BRUSHLESS D.C. DRIVE

Background Information

The present invention is directed to a brushless d.c. drive according to the definition of the species of Claim 1.

Brushless permanent-field d.c. drives are used in motor vehicles for a variety of purposes, including electric power-assisted steering. These d.c. drives have a synchronous motor having a preferably star-connected stator winding or armature winding and a permanent-field rotor. The armature winding is connected to the direct voltage network by a converter in a bridge circuit having six semiconductor power breakers. The power inverter which causes commutation of the armature winding is controlled by an electronic controller. An example of a synchronous motor operated on a direct voltage network is described in German Patent Application 37 09 168 A1.

If faults occur in the armature winding and/or in the power breakers, the d.c. drive may generate a permanent electromagnetic braking torque without a direct voltage being applied, because now the synchronous motor operates as a generator against a low-resistance load impedance. In many applications, such a braking torque has a negative effect on the functioning of the unit or system in which the d.c. drive is used. For example, in the case of electric power-assisted steering systems, the braking torque which occurs in the event of a fault necessitates a considerable steering force being applied by the driver, which is unacceptable. It is therefore known that devices can be provided on such a d.c. drive to lead to a fail-silent response of the d.c. drive in the event of a fault, i.e., the d.c. drive does not have any interfering

or negative effect on the unit or system, so the latter functions as if the drive were not present.

In the case of a known electric power-assisted steering system, a mechanical clutch, by way of which the output shaft of the synchronous motor acts on the steering gears, is used to produce the desired fail-silent response. In the event of a fault, the clutch is opened and thus the motor is uncoupled from the steering system.

Advantages of the Invention

The brushless d.c. drive according to the present invention having the features of Patent Claim 1 has the advantage that the desired fail-silent response of the d.c. drive is achieved without any expensive external components, such as mechanical clutches, with simple circuitry measures in the drive itself. Thus, the d.c. drive becomes more compact and requires less space, so that it can be used in a more versatile manner. The additional cost incurred for the desired response of the d.c. drive in the event of a fault is greatly reduced.

Advantageous refinements of and improvements on the d.c. drive characterized in Patent Claim 1 are possible through the measures characterized in the additional claims.

According to a preferred embodiment of the present invention, the separating means for separating the connections between the winding phases of the armature winding can be activated by a control unit which detects a fault case.

According to an advantageous embodiment of the present invention, the control unit has for this purpose measurement shunts in each connecting line between the armature winding and the switching device designed as a bridge circuit having

semiconductor switches. In simultaneous blocking phases of all semiconductor switches, the electric currents flowing through the measurement shunts are measured, and in the event of a current value which differs significantly from zero in one of the measurement shunts, the control device delivers an activation signal to the separating means. Such a design of the control unit with which faults occurring in the switching device are detected has the advantage that the measurement shunts already present in the d.c. drive for measuring the current for other reasons can also be used to detect the fault case, thus further reducing the complexity of the circuitry. Faults in the armature winding itself can be detected, for example, by measuring the braking torque delivered to the output shaft of the synchronous motor, which is an advantage in the case of electric power-assisted steering systems, because sensors for measuring torques on the input and output shafts are already provided in the final control elements of the electric steering devices.

According to an advantageous embodiment of the present invention, the control unit in a star connection of the armature winding has measurement shunts, each connecting a winding phase of the armature winding to the neutral point. The control unit continuously measures the amount and phase of currents flowing through the measurement shunts and adds the shunt currents as vectors. In the event of a significant deviation in the result of this addition from zero, the control unit delivers an activation signal to the separating means. With such a control unit, faults in the semiconductor switching device as well as faults in the armature winding are detected, and the separating means are activated accordingly.

According to advantageous embodiments of the present invention, the separating means may be designed in such a way that they cause a reversible or irreversible separation of the

connections between the winding phases of the armature winding. An irreversible separation can be brought about by way of pyrotechnic blasting charges or by fusible cutouts. For reversible separation, electric contacts controllable by electronic or mechanical means are used. In the case of armature windings in a star connection, the neutral point is separated, but in the case of armature windings in a delta connection, each winding phase must be separated from the winding terminations.

Drawing

The present invention is explained in greater detail in the following description on the basis of embodiments illustrated in the drawing, showing:

Figure 1	a circuit diagram of a brushless d.c. drive,
Figure 2	a circuit diagram of a modified armature winding for the d.c. drive in Figure 1,
Figure 3	a circuit diagram of the armature winding of the d.c. drive in Figure 1, having a modified control unit for controlling separating means for separating the armature winding,
Figures 4 and 5	each show the same diagram as in Figure 2 according to two additional embodiments.

Description of Exemplary Embodiments

The brushless d.c. drive illustrated in the block diagram in Figure 1 has a synchronous motor operated by a switching

device 11 for electronic commutation on a direct voltage source 10. The synchronous motor, shown here with only its stator winding or armature winding 12, has a stator which holds armature winding 12 in a known manner and a rotor which rotates in the stator and has permanent magnetic poles. Armature winding 12, which is designed in three phases, has three star-connected winding phases 13 in the embodiment illustrated in Figure 1, their terminations 1, 2 and 3 being connected to switching device 11 by connecting line 14.

Switching device 11, designed as a B6 power inverter, has six semiconductor switches 15, preferably MOS-FETS, arranged in a bridge circuit. Connecting lines 14 leading to winding terminations 1, 2 and 3 are each connected to taps 4, 5 and 6 of a bridge branch formed by a series connection of two semiconductor switches 15, which is in the connection of two semiconductor switches 15. For commutation of armature winding 12, i.e., for applying winding phases 13 to direct voltage source 10 in the correct order, semiconductor switches 15 can be controlled by an electronic controller 16.

The brushless d.c. drive has a device for forcing a fail-silent response, which ensures that in the event of a fault in the d.c. drive, possibly caused by a defective semiconductor switch 15, for example, or by a winding termination in armature winding 12, this does not interfere with or have a negative effect on the system working with the d.c. drive. This device includes separating means which, in the event of a fault, separate the connections between winding phases 13 and a control unit 17, which is integrated into controller 16 and, in the event of a fault, detects the fault case on the one hand while on the other hand also activating the separating means. In the embodiment according to Figure 1, three measurement shunts belong to control unit 17, one being connected to each of three connecting lines 14 between

switching device 11 and armature winding 12.

In time intervals during which all semiconductor switches 15 are blocked, control unit 17 measures the shunt currents flowing over measurement shunts 18. If all semiconductor switches 15 are intact, each shunt current is zero. If control unit 17 measures a value which differs significantly from zero in one of measurement shunts 18, it generates an activation signal which is delivered to the separating means and activates them.

In the embodiment according to Figure 1, the separating means act on neutral point 20 of armature winding 12, causing an irreversible separation of the neutral point connection of winding phases 13 when activated. The separating means here are designed, for example, as a pyrotechnic blasting capsule 19, such as that used in motor vehicles to deploy airbags in the event of a crash, for example. Electrically ignitable blasting capsule 19 is connected first to control unit 17 by way of a connecting line 40 and second to the negative potential of direct voltage source 10. If one of measurement shunts 18 delivers a current value differing significantly from zero, control unit 17 generates an electric firing pulse which ignites blasting capsule 19. The exploding blasting charge ruptures neutral point 20, thus separating winding phases 13 from one another. In this way, the in-system d.c. drive, which is driven by the system by way of its output shaft in the event of a fault, cannot generate a braking torque because separated armature winding 12 does not allow generator operation.

With control unit 17 described in conjunction with Figure 1, only faults based on defects in semiconductor switches 15 can be detected. To also detect possible faults occurring in armature winding 12, control unit 17 according to Figure 3 is

modified so that measurement shunts 18 present in feeder lines 14 are eliminated, and instead measurement shunts 21 are arranged between neutral point 20 and each winding phase 13. Control unit 17 measures the amount and phase of electric currents flowing over measurement shunts 21 and adds them as vectors. In a fault-free d.c. motor, the result of this addition is always zero. If the vector sum differs significantly from zero, control unit 17 in turn generates an activation signal for the separating means, which here are also acting on neutral point 20. In the embodiment illustrated in Figure 3, the separating means have a fusible cutout 22 which is heated briefly on activation by control unit 17 so that it melts through and thus separates neutral point 20. A heater coil 24 connected to direct voltage source 10 by way of a power breaker controlled by control unit 17 is used to heat fusible cutout 22.

Armature winding 12 of the synchronous motor may of course also be connected in a delta connection, for example, as illustrated in the circuit diagram in Figure 2. Winding phases 13 here are connected to winding terminations 1, 2 and 3. The separating means for separating winding phases 13 in the event of a fault are integrated into winding phases 13 and connected in series with them. In the embodiment in Figure 2, the response of the separating means causes a reversible separation of armature winding 12. To this end, an electric switching contact 23 which can be controlled by electronic or mechanical means is arranged between winding terminations 1, 2 and 3 and winding phases 13. Electronically controllable switching contacts 23 are implemented by transistors or thyristors, for example, and mechanically controllable switching contacts 23 may be designed as electromagnetic relays, for example.

In the embodiment in Figure 4, like the embodiment according

to Figure 1, the separating means are arranged at neutral point 20 of armature winding 12; when activated, they cause an irreversible separation of neutral point 20. The separating means have two switching contacts 25 which are preloaded in the direction of opening and are each held in the closed position by a holding element 26. A switching contact 25 having a holding element 26 is arranged between neutral point 20 and the end of the winding of each of two winding phases 13. It is not necessary to provide a third switching contact having a holding element between neutral point 20 and third winding phase 13. A common electrically ignitable pyrotechnic blasting capsule 27 is provided for both holding elements 26 and is designed so that it is capable of destroying both holding elements 26 when deployed. As in the embodiment according to Figure 1, blasting capsule 27 is connected by connecting line 40 to control unit 17 which applies an electric firing pulse to blasting capsule 27 in the event of a fault. With destruction of holding elements 26, prestressed switching contacts 25 are released and they open, so that the connection of two winding phases 13 to neutral point 20 is interrupted suddenly.

Figure 4 schematically shows a structural embodiment for two switching contacts 25 which are prestressed in the direction of opening and have a holding element 26 and a common blasting capsule 27 for holding elements 26. Each switching contact 25 has a contact plate 28 fixedly connected to an operating pin 29. Axially displaceable operating pin 29 is loaded by a compression spring 30 which is supported on a spring plate 31 connected to operating pin 29 and on a stationary stop 32 and prestresses operating pin 29 so that contact plate 28 is lifted up from contact points 33, 34. Both holding elements 26 have a common lock block 35 in which both operating pins 29 engage, each with a locking projection 36 provided on its end which faces away from contact plate 28. When ignited, blasting

capsule 27, which is arranged inside lock block 35, destroys lock block 35. In assembly, switching contacts 25 are closed by pressing contact plate 28 against contact points 33, 34 with tensioning of compression springs 30, so that locking projection 36 falls into lock block 35 and is held there. In the case of a fault, blasting capsule 27 is ignited by control unit 17. This destroys lock block 35, thus releasing operating pins 29, and prestressed compression springs 30 lift contact plates 28 away from contact points 33, 34.

In the embodiment according to Figure 5, as in the embodiment according to Figure 2, armature winding 12 is connected in a delta connection. It is necessary here for each branch of the delta connection to be separated in the event of a fault, so that a switching contact 25 having a holding element 26 is connected to each winding phase 13 in series. In the embodiment according to Figure 5, a separate blasting capsule 27 is provided for each holding element 26, destroying holding element 26 when deployed, so that switching contact 25 which is prestressed in the closing direction opens automatically. It is of course also possible to use a common blasting capsule 27 to destroy all three holding elements 26. Prestressed switching contacts 25 having holding element 26 may be designed as described in conjunction with Figure 4. In the design of switching contacts 25 as prestressed spring tongues, separate compression springs 30 for opening switching contacts 25 may be omitted.